Produced Water Treatment – A Challenge

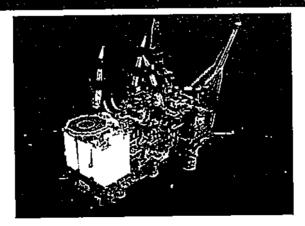
The Cause

New compositions due to tie-in from new wells
Increasing water cuts
Presence of chemicals and suspended particles
Water salinity
Aging in the system

The Effect

Too small and stable oil droplets for efficient separation

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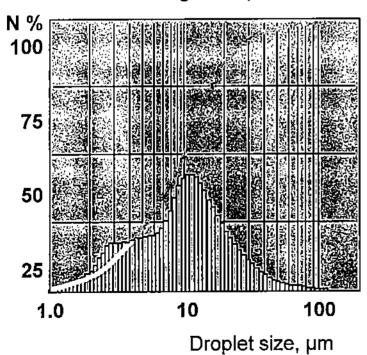




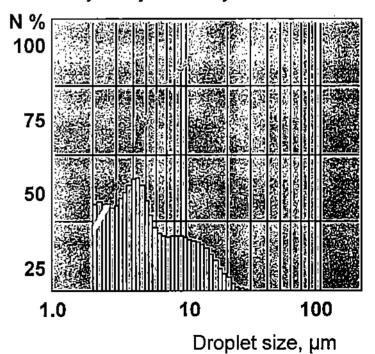


The Challenge: Small Oil Droplets

Typical droplet size distribution in water from gas lift production



Typical droplet size distribution in hydrocyclone reject

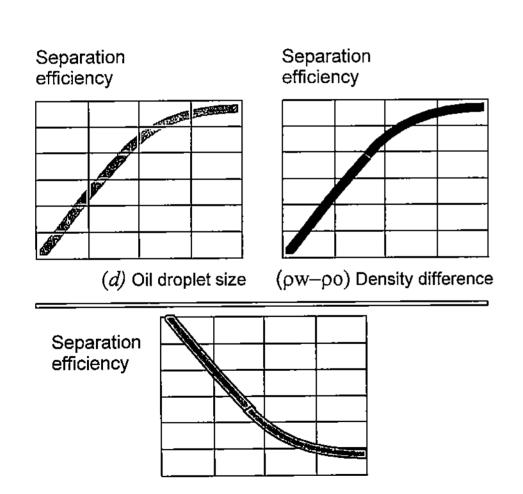




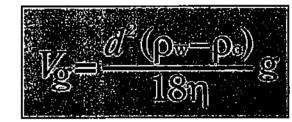
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Droplet Size and Settling Velocity

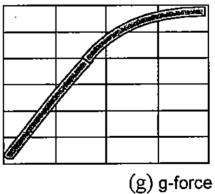
The Smaller the Droplets the Lower the Separation Efficiency



Stokes' Law



Separation efficiency

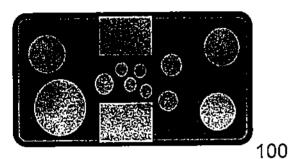




Mechanical Break-up of Droplets

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Droplet generation by choke valve

Droplet size created as a function of pressure drop

Average volumetric diameter, µm

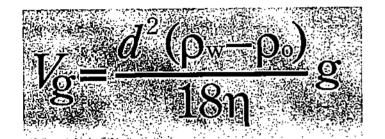
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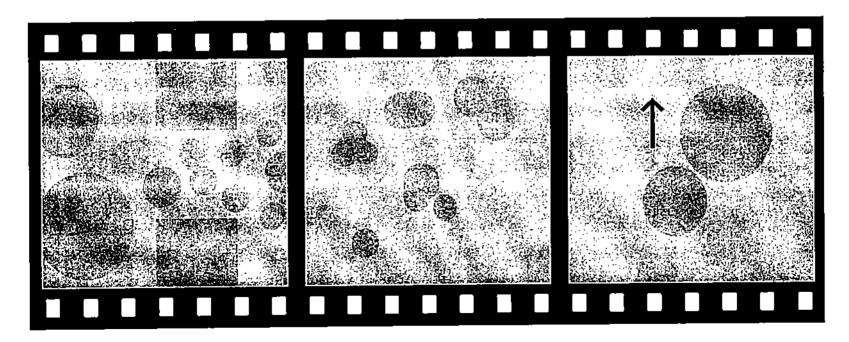
Pressure drop, bar



Coalescence

A Prerequisite for Separation

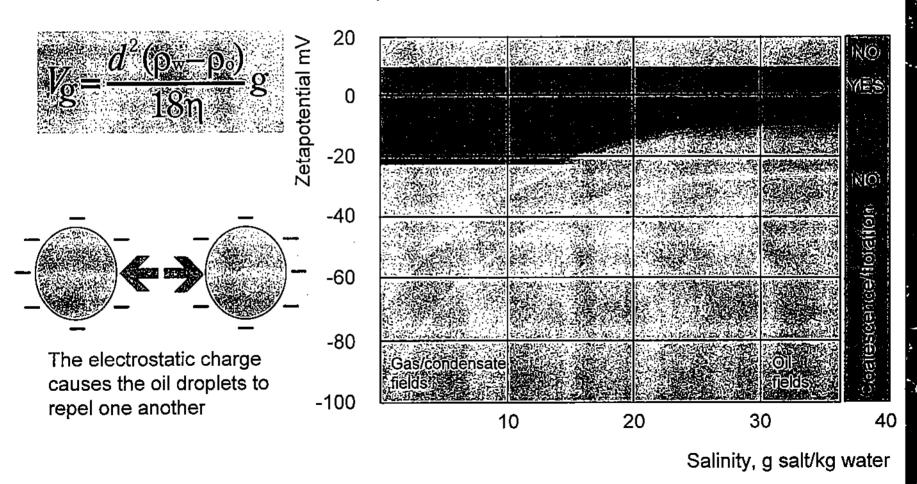






Water Salinity and Coalescence

The effect of water salinity (and electrostatic charge) on droplet coalescence

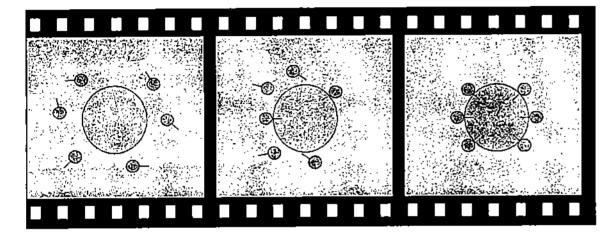




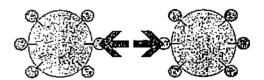
Ageing and Coalescence

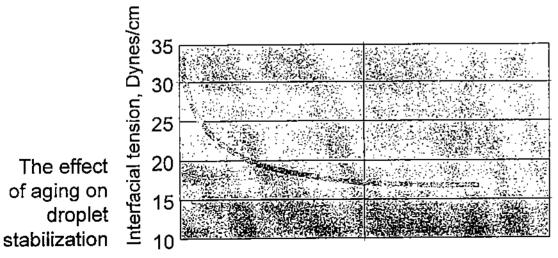
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The effect of suspended particles and surface active chemicals





$$\mathbb{D}_{\max} = \mathbb{C}\left(\frac{\mathbb{S}^{0.6}}{\mathbb{E}^{0.4} \cdot \mathbb{P}^{0.2}}\right)$$

Hinze's equation

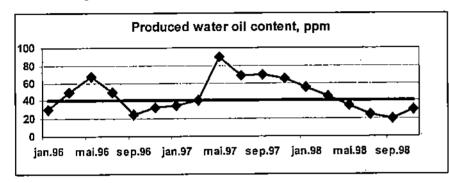
Time, minutes

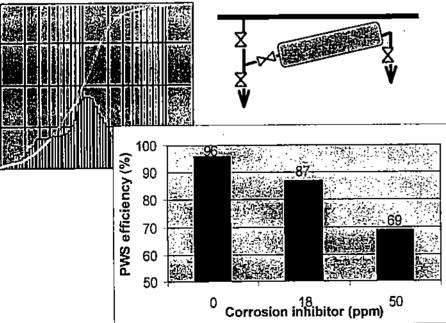
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Mapping the Process

The Key to Solving the Separation Problem

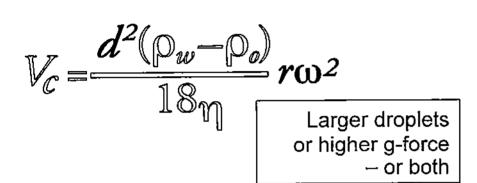




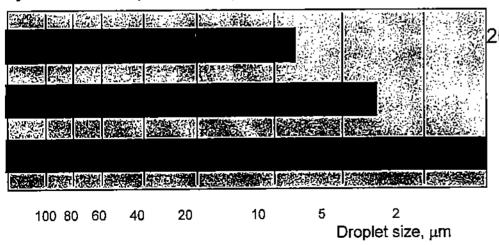
- Optimize separator operations w.r.t produced water quality
- Optimize hydrocyclone and degasser performance.
- Test and select the best performing produced water chemical, including adjustment of the dosage rate.
- Testing of alternative produced water equipment.
- Study the effects of recirculated streams on produced water quality.
- Testing and analysis of produced water w.r.t. reinjection.

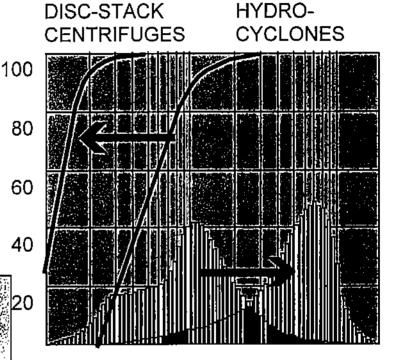


Separation Efficiency vs Droplet Size



Smallest oil droplets removed by different separation systems



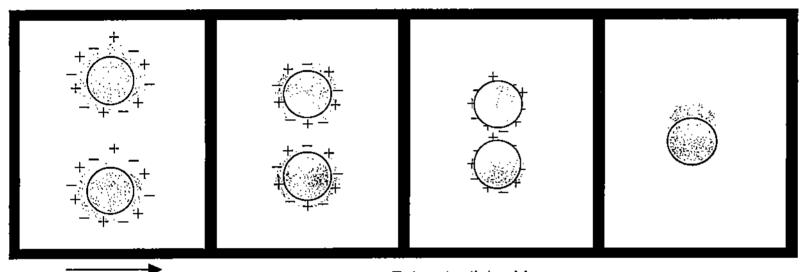


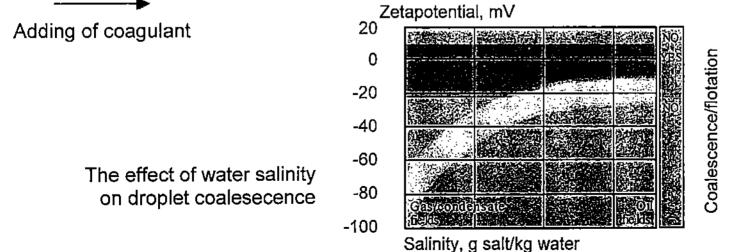
Separation efficiency,

Droplet size, µm



Coagulation Stage One in the Hydroflokk System



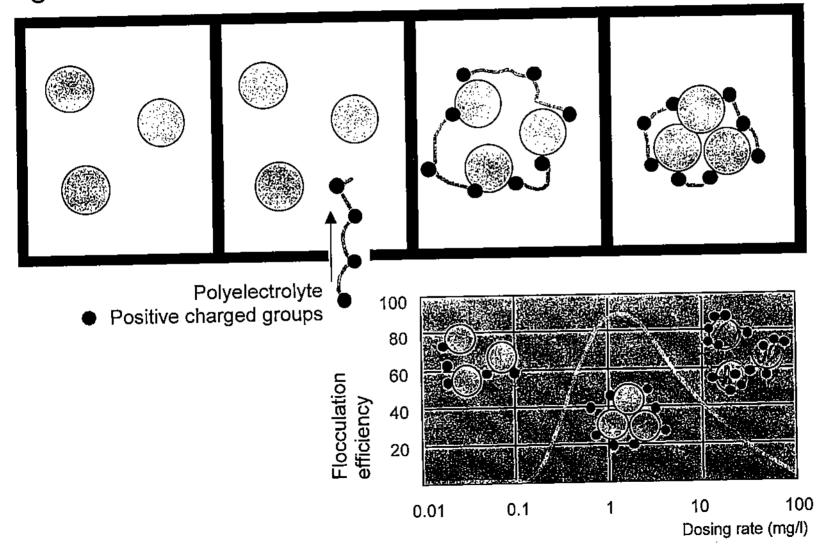




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Flocculation B

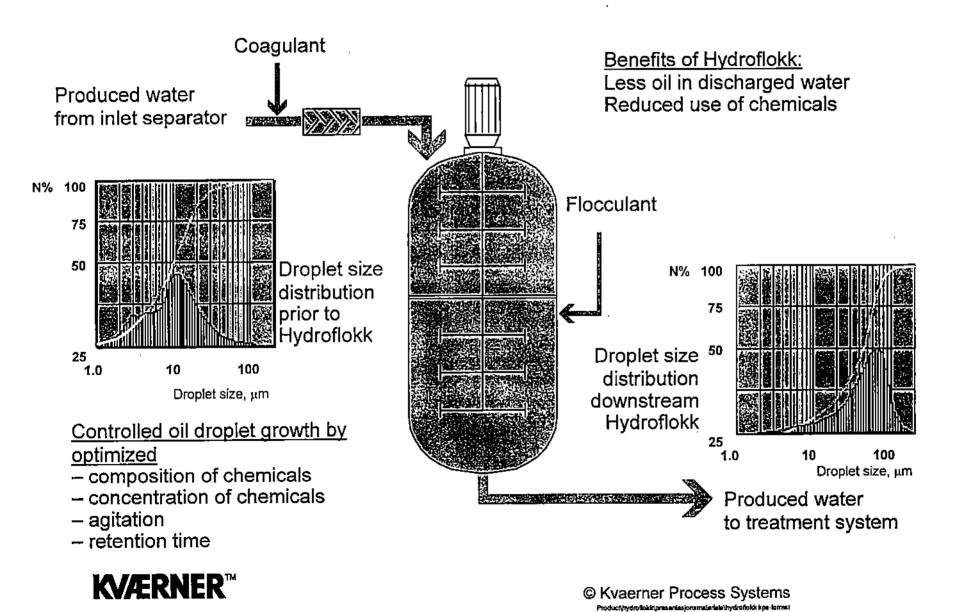
Stage Two in the Hydroflokk System





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A Look at the Hydroflokk System



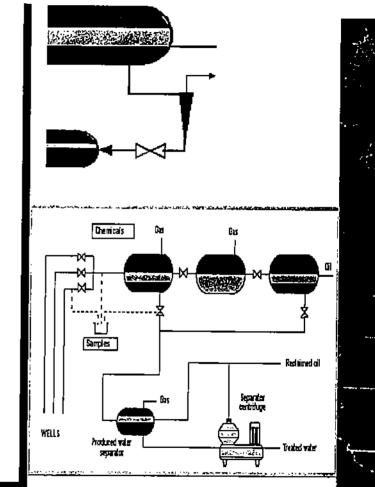
Benefits of Hydroflokk

- Consistent and acceptable discharge water quality
- Improved performance from deoiling hydrocyclones
- Optimised chemical performance
- Substantially reduced operating costs
- Greater flexibility of the separation process
- Potential to realise improved oil quality
- Potential for debottle-necking existing systems



Troll B challenges

- Large volumes !!Q = 40 000 Sm3/d = 252 000 blpd
- High concentration !!OiW = 500 1 500 ppm
- Small oil droplets !!dv50 = 5 µm
- Low target value for disposal !!
 Discharge OiW target = 25 ppm



How to handle this ??

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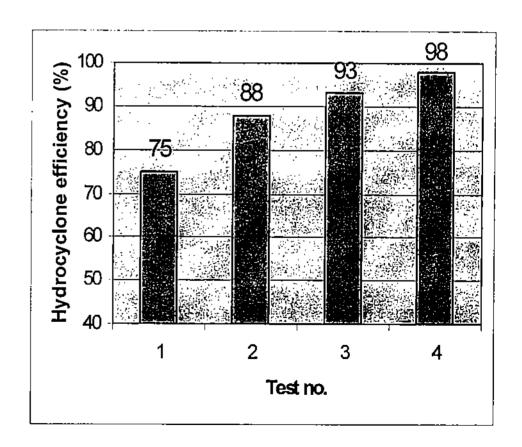
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Pilot plant test results

Conditions: P=12barg, T=50°C, OiW=1000ppm, d_{v50}=5µm, reject=2-3%

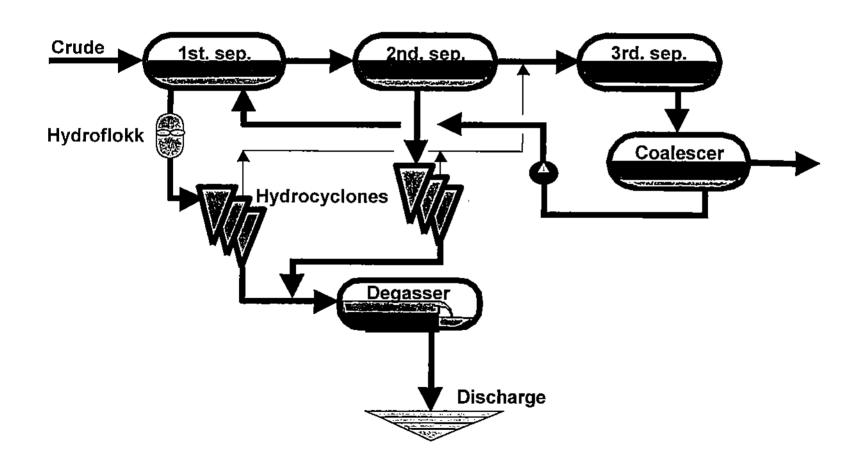
Test no.:

- 1. Hydroflokk not included.
- 2. Flocculation vessel included, no chemicals.
- 3. One component system.
- 4. Two component system.





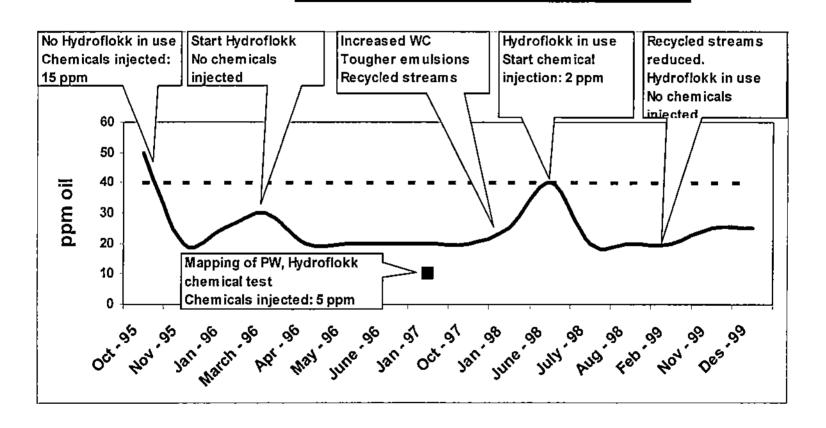
Troll B flow diagram





Troll B History

Troll B - oil in water discharge





Troll C flow diagram

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